Rio Grande municipal dump site impact in the estuary of the Patos Lagoon (RS, Brazil).

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ABSTRACT: Rio Grande municipal dump site impact in the estuary of the Patos Lagoon (RS, Brazil). The solid waste from the Rio Grande City has been deposited on the margins of the Saco do Martins (Patos Lagoon estuary) for over three decades. The Saco do Martins is considered a preservation area since 1995 according to the Foundation of Environmental Protection of the Rio Grande do Sul State (FEPAM/RS), and anthropic waste is not allowed. To evaluate the contamination of these waters and the influence of the water regimen in this region of the Patos Lagoon estuary in the dispersion of the deriving contaminants of the dump site, seasonal surface water samplings were collected (in different saline conditions). The sampling was taken in eleven sites distributed along the shore side of the dump site and four sites in a stream which receives the leachate from this site. Samples were also taken from about 7 km from the garbage deposit, as a control, in order to avoid its influence. The following parameters were analyzed: nutrients, chlorophyll (a), physical and chemical parameters, as well as trace metals in leachate samples. Results showed that margin waters presented the highest contamination. In particular the increase of nitrogenated compounds in spring time was evident when the lagoon condition was less saline, promoting the eutrophication and consequently the increase of chlorophyll (a) in these waters. When the salinity was high in the summer, the contamination of nitrogenated compounds was low, probably because of the dilution processes. However, concentration of phosphate was higher in more saline water, which was probably due the liberation of phosphate from the interstitial water of the contaminated sedimentary column. The leachate flowing into the stream next to the dump site are causing contamination in this system, mainly related to ammoniacal nitrogen and lead contents, consequently indicating input of those elements to the Saco do Martins margin waters.
Key-words: dump site, estuary, leachate, contamination.

RESUMO: Impacto do lixão municipal do Rio Grande no estuário da Lagoa dos Patos (RS, Brazil). O lixo do município do Rio Grande vem sendo depositado nas margens da enseada do Saco do Martins (estuário da Lagoa dos Patos) há aproximadamente três décadas. Esta região é classificada pela Fundação Estadual de Proteção Ambiental do estado do Rio Grande do Sul (FEPAM/RS) como uma área de preservação desde 1995. Desde então não é permitido nenhum tipo de lançamento antrópico. Para avaliar a contaminação dessas águas e a influência do regime hídrico do estuário da Lagoa dos Patos na dispersão dos contaminantes oriundos do lixão, foram realizadas amostragens de água superficial em cada estação do ano (em diferentes condições salinas). As amostras foram coletadas em onze pontos distribuídos ao longo da costa e quatro pontos em um córrego, o qual recebe o chorume do lixão. Amostras, como controle, foram coletadas a cerca de 7 km de distância para evitar a influência do lixão. Os seguintes parâmetros foram analisados: nutrientes, clorofila (a), parâmetros físico e químicos, além de metais traço nas amostras de chorume. Os resultados mostraram que as águas junto à margem apresentaram os maiores contaminações. Destaca-se o aumento dos compostos nitrogenados na primavera, quando a água estava menos salina, favorecendo a eutrofização e um conseqüente aumento de clorofila (a) nessas águas. No verão, quando a salinidade estava alta, os níveis de contaminação de compostos nitrogenados foram baixos, provavelmente devido aos processos de diluição. No entanto, as concentrações de fosfato foram mais elevadas na presença de água mais salina, o que pode ter sido devido à liberação de fosfato a partir da água intersticial da coluna sedimentar. O deságüe do chorume no córrego adjacente ao lixão resultou na contaminação do mesmo principalmente com relação a nitrogênio amoniacal e chumbo, consequentemente indicando aporte destes elementos para a margem do Saco do Martins.
Palavras-chave: lixão, estuário, chorume, contaminação.

Introduction

Solid wastes are any material proceeding from man's daily activities in society, whose producer or proprietor does not consider them with enough value to be conserved. In many countries, the solid wastes are discharged in uncontrolled dump sites, without any concern with the disposition technique or environmental implication. This can generate problems of public health and degradation of the environment, due to the contamination of the natural resources, as well as social problems (when people go to the dump site and irregularly collect recyclable trash) (CETESB, 1997).

The main environmental degradation caused by the dump sites is leachate, a dark liquid formed by the water that percolates through the garbage containing organic substances that support the bacterial degradation activity. When the leachate drains into superficial waters adjacent to the dump site or percolates in the soil and enters in contact with the underground waters, it alters the natural composition of these resources, introducing several compounds, as nutrients resultants of the degraded organic matter, organic compounds and metals.

In Rio Grande City (situated in the South area of the coastal plain of Rio Grande do Sul State, population size of 186.544 inhabitants), the garbage has been discharged in an open deposit, for more than thirty years. This dump site is located at the margins of the Saco do Martins which is part of the Patos Lagoon estuary. According to the State Foundation of Environmental Protection of the State of Rio Grande do Sul (FEPAM, 1995), with a base in the Resolution n° 20 of the National Council of the Environment (CONAMA, 1986), the waters from the Saco do Martins were classified as being destined to the preservation of the aquatic communities' natural balance, not being allowed any type of anthropic launching.

Since 1991, the city has been claimed by the Government because of the dump site irregularities, having a condemnation to readjust the place and immediately recover the degraded area (Ministério Público, 2002). A new area has already been determined for the construction of a sanitary landfill, whose project already possesses a previous license from the FEPAM. However, even with the shut down of the dump site, the solid residues deposited there will continue to pollute the area since there is no prevision to transpose them to another site.

Researches in the disposal area of this municipal dump are scarce, mainly those related to the environmental impact. It stands out that there is no published data about the water quality in the area in front of the dump site up to now.

Therefore, the objectives of this study were: a) to evaluate if the water of the Saco do Martins suffers alterations in its natural composition because of the leachate runoff and rejects from dump site; b) to evaluate the influence of the water regimen of this estuary region in the dispersion of the pollutants originated in the dump site; c) to supply initial data for futures monitoring studies of the water quality to help out designing a management plan for the area and d) to contribute to the mitigation activities of the dump site impact.

Study area

The solid waste material of the Rio Grande City is deposited in an open place, at the margins of the estuarine area of the Saco do Martins, located in front of the Leonídeo Island (Fig. 1), in which communities of fishermen reside. In this estuarine area, nets are placed mainly for shrimp fishing, primarily income source for the local and municipal community. The municipal dump site is also located next to a neighborhood of the Rio Grande City, which stresses its impact in the area.

The dump site occupies an area of approximately 4000 m², being its height about 17 m at the highest site. This dump site does not receive anymore residues from hospitals and industries (Municipal Services Secretary, personal communication).

The leachate from this dump site is not predominantly exposed in the surface, where it is formed. There are several ways where it drains to, such as: the stream that crosses the lateral of the dump site; the marshy area present in the area; the salt marsh that separates the dump site from the estuary and the puddles of water that are formed by the rain that is accumulated among the garbage hills. In addition, the leachate formed can infiltrate in the sandy soil that supports the dump site, already covered by old deposits of compacted garbage.

Material and methods

Sampling and Analyses of the Estuarine Water

Due to the intense annual variations in the lagoon water regimen, in the present study four water samplings were realized, one in each season: spring (November/2004), summer (February/2005), autumn (May/2005) and winter (August/2005). All samples were collected during the morning.

To establish a possible gradient of pollutants originated from the dump site rejects, a sampling network was structured in the form of three perpendicular radial to the margin of the Saco do Martins, in a total of 11 sampling sites, whose depth varied from 10 to 130 cm. A control sampling site was also used, which was about 7 km away from the direct influence of the dump site. This site was located at the margin of the Pombas Island (Fig. 1).

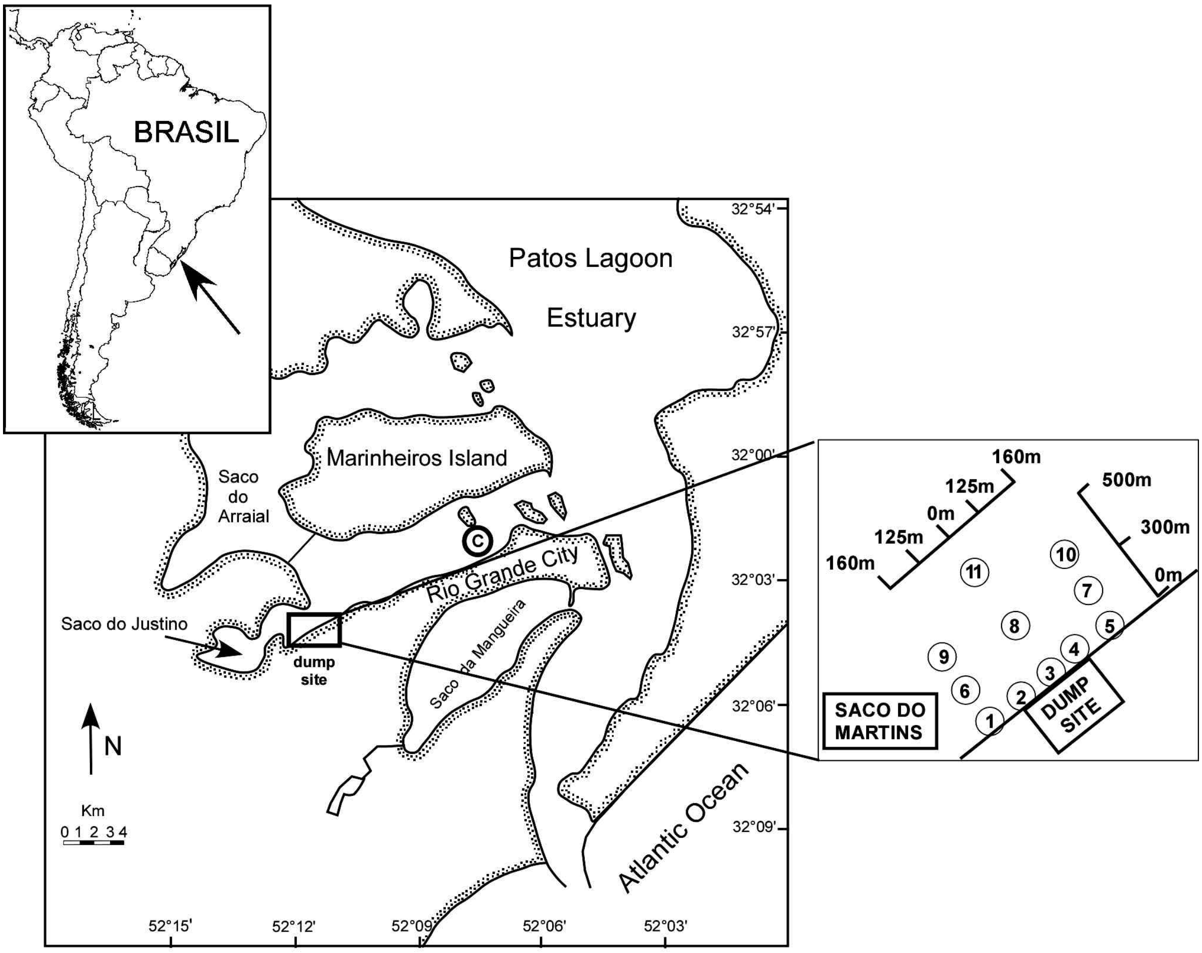

Figure 1: South region of the Patos Lagoon estuary and, highlighted, the sampling network structured in front of the dump site area; ã : location of the control site.

The following parameters were determined in the field for the surface water column: the pH using a potentiometer Model Mettler Toledo MP120, the temperature with a mercury thermometer and the depth with a scaled rope. In addition, samples of water were taken to measure salinity, dissolved oxygen and its saturation, biochemical oxygen demand (BOD_5), suspended material and its mineral and organic fractions, nutrients (ammoniacal nitrogen, nitrite, nitrate and phosphate) and chlorophyll (a). In the field just samples for dissolved oxygen analysis was fixed adding 1 mL of $MnSO_4$ and 1 mL of KI for 300 mL of sample. Biochemical oxygen demand and chlorophyll (a) samples were kept in dark bottles to avoid photosynthesis, without the addition of any reagent. Samples collected for other parameters did not receive any special treatment, besides being kept cold until they arrived in the laboratory.

The salinity was determined by conductivimetry; the dissolved oxygen and the BOD_5 were analyzed by titrimetry; the nitrite, the nitrate and the phosphate were analyzed following visible UV espectrophotometric methods; the suspended material (MS) was determined by gravimetric volatilization. All these methods, as well as the calculations of the percentile of oxygen saturation and of ammonia, were made according to methodologies described by Baumgarten et al. (1996).

The ammoniacal nitrogen was analyzed according to the method of Koroleff (1969), described by Grasshoff et al. (1983). The chlorophyll (a) concentrations were determined following the Lorenzen method (1967), described by Parsons et al. (1984).

For the calculations of the percentile of mineral (fixed residue) and organic (volatile residue) matter of the suspended material, the filters used in its filtration were calcinated at 550°C for 3 hours (APHA, 1992).

The treatment of the data was done by a non parametric test of variance analysis (Kruskal-Wallis ANOVA), in the level of significance of 5%, to identify two variations: spatial ("margin" group, sites 1 to 5, and "channel" group, sites 6 to 11) and seasonal (groups spring, summer, autumn and winter). The interpretation of the analysis of seasonal variance was made in agreement with the three saline conditions verified: fresh water (up to 5 of salinity), salty water (above 25) and mixohaline water (salinity between 8 and 11). This allowed to better evaluate the temporary variation of the results, the influence of the presence or not of the salty water or the water regimen in the quality of the water of the area studied, and the contamination caused by the rejects of the dump site.

Composition of the Leachate

To determine the pollutant potential of the leachate samples were taken at a stream of approximately 13 cm deep and 50 cm wide located next to the dump site (August/ 2005). According to the Fig. 2, sampling sites A, B and C were located in the stream, and the site D, about 10 m into the estuary, represented the dilution of the leachate.

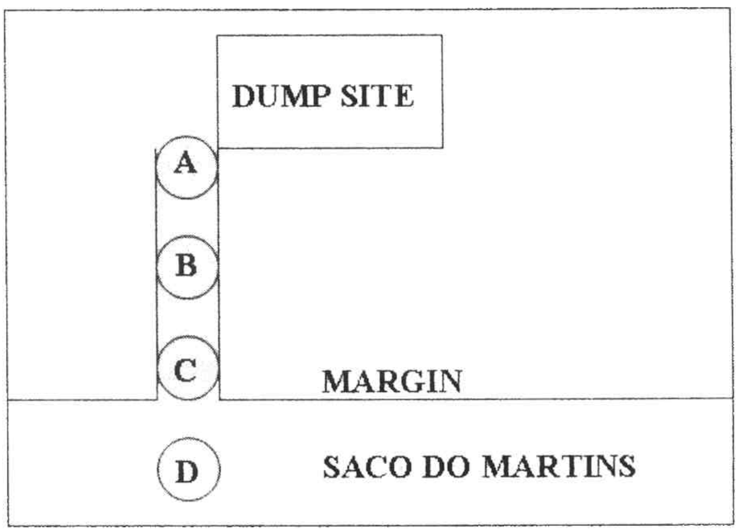

Figure 2: Scheme of the sampling sites in the stream that receives the leachate from the dump site.

The four samples collected where analyzed for the same previously described parameters. Dilutions, due to the high pollutant concentrations, were made when necessary (20% dilution for colorimetric analyses and 5% for the BOD_5 analysis). The trace metals cadmium (Cd) and lead (Pb) were also analyzed. Samples were acidified in the field in the proportion of 1 mL of concentrated HNO_3 suprapure for one liter of sample.

To obtain the total fraction of metals (Cd and Pb) in the water, samples were digested according to CEM (1994). After the digestion, the concentrations of the trace metals were analyzed by flame atomic absorption spectrophotometer (CG AA 7000 SBC).

The results of the samples collected at the stream were compared with the limits recommended by the Resolution n° 357, CONAMA (2005), in Chapter IV for condition and standard of effluents launchings.

Results

Leachate

The results of the chemical variables analyzed as contamination indicative of the water (ammoniacal nitrogen, nitrite, nitrate, phosphate (phytonutrients), ammonia, BOD_5 and chlorophyll (a)), presented the highest contaminations in the samples collected closer to the dump site (sites A and B) (Fig. 3).

As for the salinity, the dissolved oxygen and its saturation, the suspended material and its mineral fraction, their concentrations showed a tendency contrary to the one described previously, that is, they increased from the site A in direction to the site D. This same tendency was also observed for lead and cadmium results (Tab. I).

The temperature stayed constant in the sites A, B and C (16°C), suffering an increase in the site D (16.6°C). The same pattern of little variations was also observed for the pH values (Fig. 3).

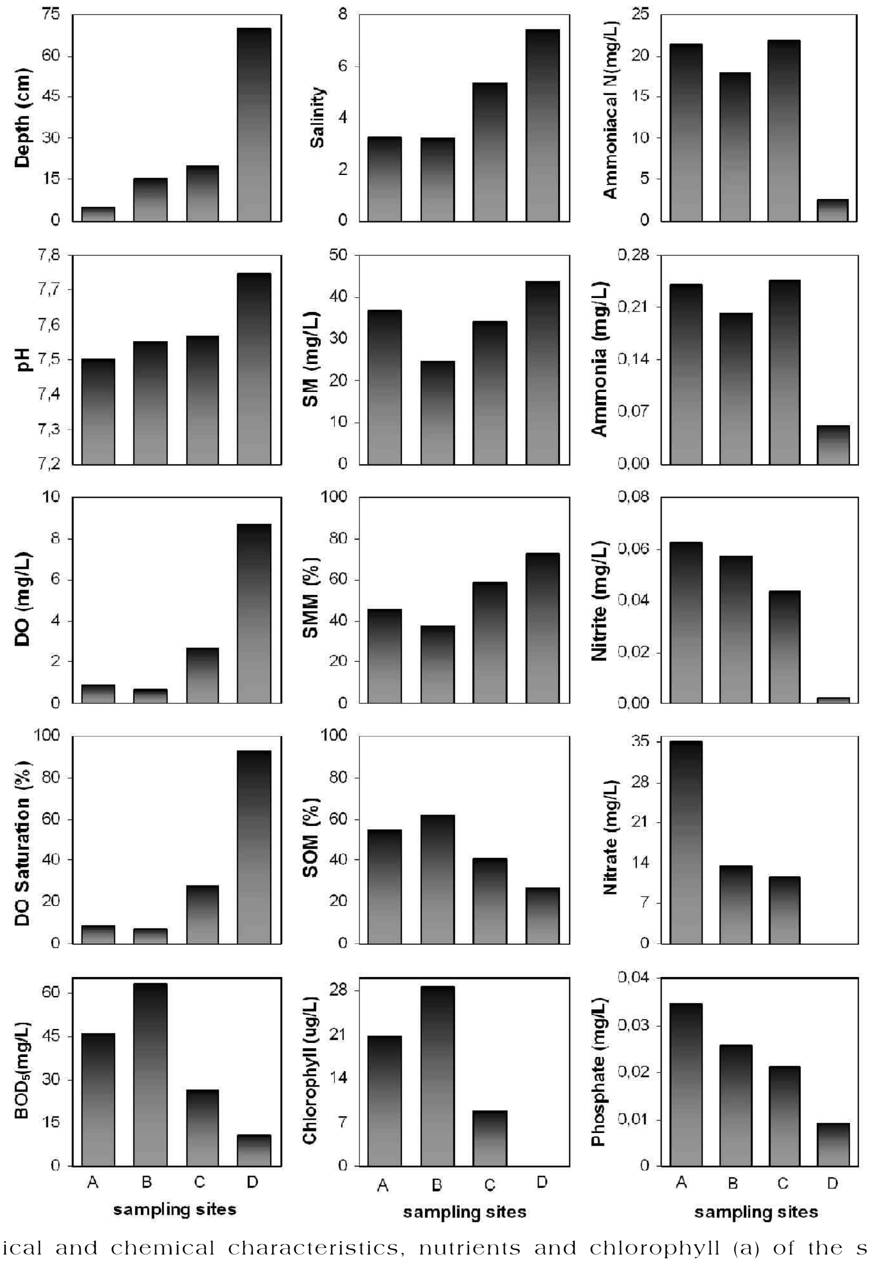

Figure 3: Physical and chemical characteristics, nutrients and chlorophyll (a) of the stream that receives the leachate from Rio Grande's municipal dump site during the winter (August 2005). (DO: dissolved oxygen; BOD_5: biochemical oxygen demand; SM: suspended material; SMM: suspended mineral material; SOM: suspended organic material; Ammoniacal N: ammoniacal nitrogen).

Table I: Concentrations (mg/L) of cadmium (Cd) and lead (Pb) in the streamwater that receives the leachate from Rio Grande's municipal dump site during August 2005 compared with the maximum limits established by the legislation (CONAMA, 2005) for effluent launching.

Collection sites	Cd (mg/L)	Pb (mg/L)
A	0.023	0.933
B	0.012	1.200
C	0.032	1.067
D	0.038	1.600
Legislation	0.2	0.5

Estuary

Some parameters did not present considerable differences therefore, only relevant results are discussed here. This is the case of salinity, temperature and phosphate, which did not present evident spatial variation in their concentrations.

The data analysis indicated that the lowest pH values (higher acidity), oxygen and its saturation occurred in the sites near the margin, where the water column is shallower. In those sites it was also registered the highest concentrations of ammoniacal nitrogen, nitrite, nitrate, chlorophyll (a) (Fig. 4), suspended material and its mineral fraction (Fig. 5).

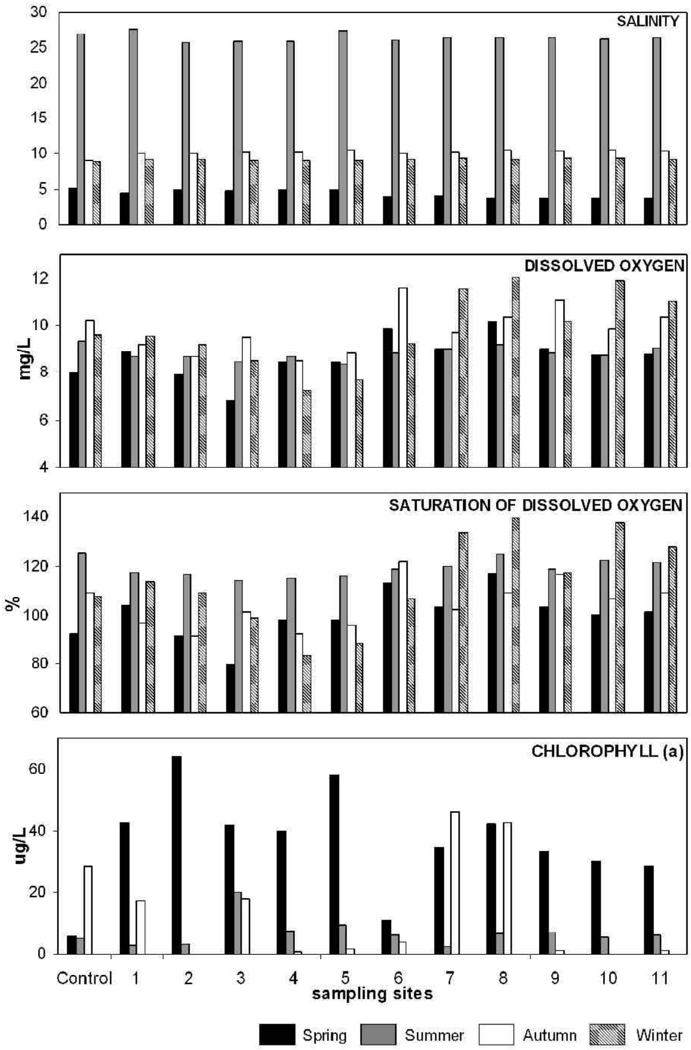

Figure 4: Salinity, dissolved oxygen, its saturation and chlorophyll (a) of water samples collected in front of Rio Grande's municipal dump site, during the spring (November/2004), summer (February/2005), autumn (May/2005) and winter (August/2005).

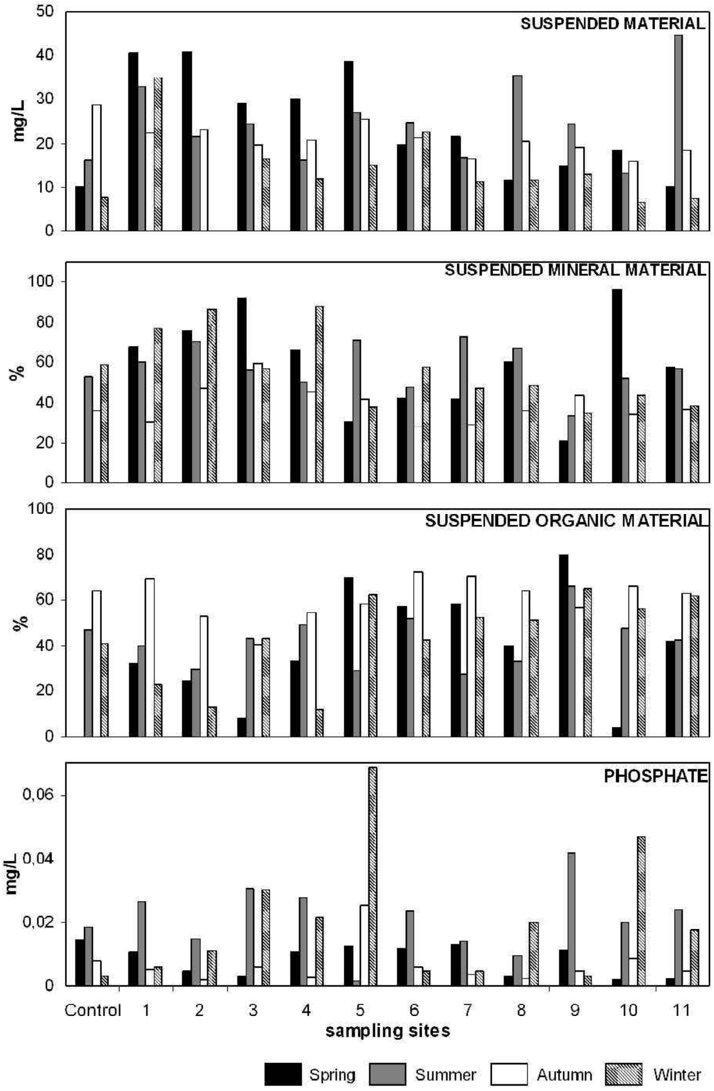

Figure 5: Suspended material, its mineral and organic fractions and phosphate of water samples collected in front of Rio Grande's municipal dump site, during the spring (November/2004), summer (February/2005), autumn (May/2005) and winter (August/2005).

The nitrite concentrations became very low in the sites sampled in the channel, unlike the nitrate concentration that increased (Fig. 6).

The seasonal variation (Fig. 4 and 5) showed that the salinity was higher in the summer, when the salty water (above 25) prevailed. In the spring occurred the presence of fresh or slightly saline water (up to 5 of salinity). In the autumn and winter the same saline condition was verified, in other words, mixohaline water (salinities between 8 and 11). Just in the winter sampling flooding regimen was registered, in the others the water ebbing the estuary.

In the spring sampling period it was observed the highest values of chlorophyll (a) (64.08 mg/L), nitrite (0.063 mg/L), nitrate (0.244 mg/L) and ammoniacal nitrogen (0.882 mg/L) at the margin area (sites 1 to 5). In the same period and location lowest values of organic fraction of suspended material (7%), dissolved oxygen (6.83 mg/L) and its saturation (79.67%) were analyzed (Fig. 4 and 6).

During the summer sampling period in the channel the highest values of salinity, phosphate (0.042 mg/L) and suspended material (44.6 mg/L) were evident (Fig. 4 and 5).

In the autumn the highest values of ammoniacal nitrogen (1.17 mg/L) was only observed at site 4. Contents of nitrogenated compounds and organic matter were high in the margin waters but lower than values found during the spring period (Fig. 5 and 6).

In the winter the lowest mean values of ammoniacal nitrogen (0.008 mg/L), nitrite and nitrate (0.001 mg/L), chlorophyll (a) (0.01 mg/L) and suspended material (6.57 mg/L) were observed in the channel. The highest content of organic material (65.22 %), phosphate (0.068 mg/L), dissolved oxygen (12.05 mg/L) and its saturation (139.66%) were measured in the same period.

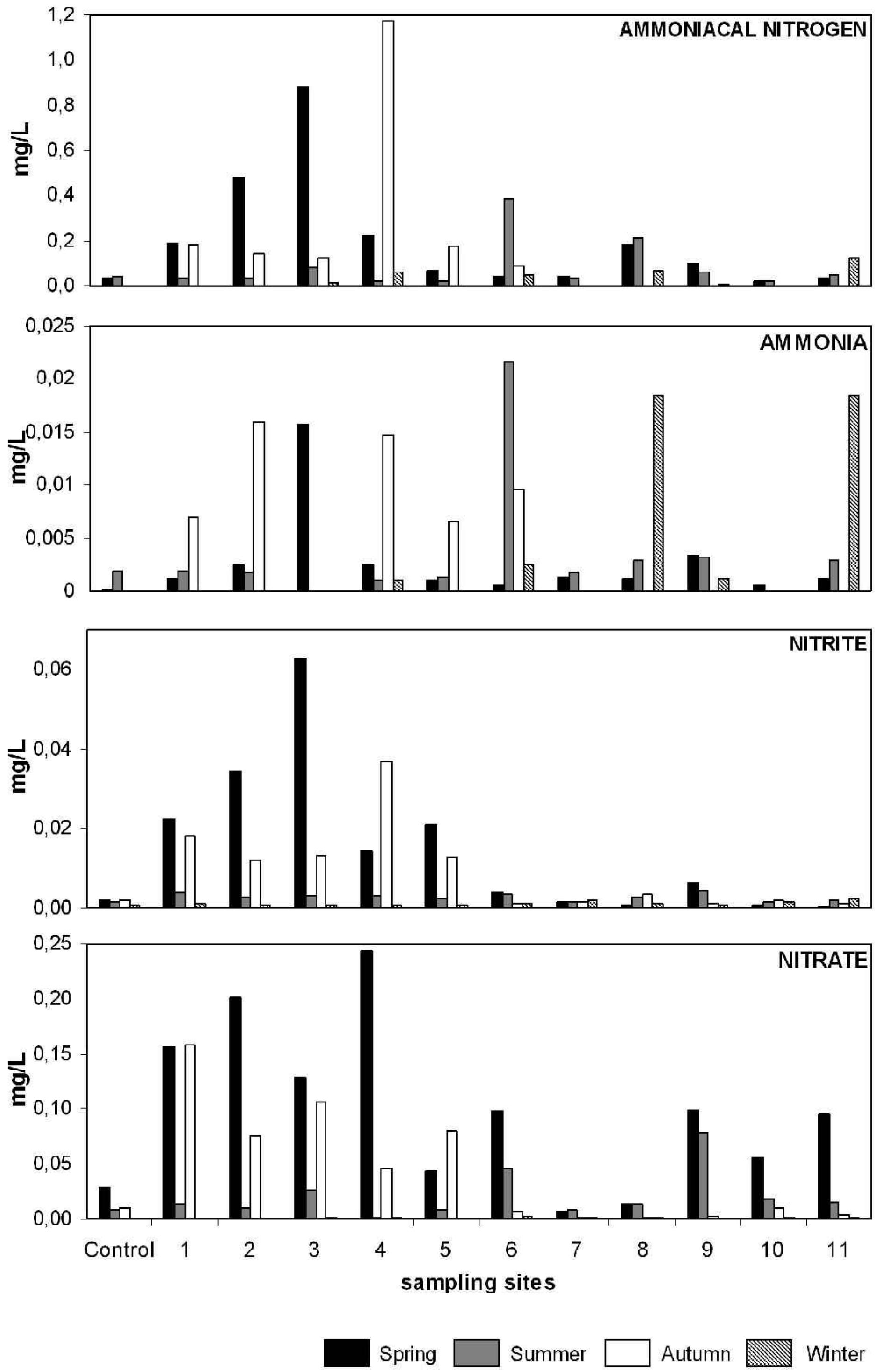

Figure 6: Nitrogenate compounds of water samples collected in front of Rio Grande's municipal dump site, during the spring (November/2004), summer (February/2005), autumn (May/2005) and winter (August/2005).

Discussion

Leachate

The results evidenced the environmental pollutant potential of the leachate in the study area, on the condition in which it was sampled, more specifically in the winter with flooding regimen of the estuary.

The clear increase of the salinity in the stream that receives the leachate, from inland to the Saco do Martins evidenced a gradual dilution with the open water, even before the stream reaches the estuary. It indicated that, during the sampling, the more saline water from the estuary was penetrating inside the stream. Another hypothesis for the salinization of the stream could be the diffusion of the interstitial water from the sediment pores to the water column, in a search of ionic balance among these two water masses. This enrichment process of the water column starting from the more enriched interstitial water was intensely registered in the Saco do Justino, which is adjacent to the Saco do Martins (Baumgarten et al., 2005).

The enrichment of ammoniacal nitrogen of the stream was probably caused by the microbiologic decomposition of the organic matter originated from the dump site. This enrichment stood out due to the high concentrations of this dissolved nutrient in the site A (21.41 mg/L) and C (21.94 mg/L). Those concentrations exceeded the maximum limit stipulated by the environmental legislation which is 20 mg/L for effluent launching (CONAMA, 2005). Exception was found for the site D.

A fraction of the ammoniacal nitrogen is constituted of ammonia, thus the contamination of both, ammoniacal nitrogen and ammonia, normally occurs simultaneous, as it was demonstrated in the stream, where the concentrations of ammonia were 10 times larger than the maximum value of 0.02 mg/L cited by Train (1979), which is the limit of significant toxicity to the biota. Besides this high concentration, the interaction between ammonia and dissolved oxygen is also an important factor for the ammonia toxicity, which is inversely proportional to the oxygen concentration (Rand & Petrocelli, 1985). Such decrease in the concentrations of dissolved oxygen was also observed in the stream.

The intense subsaturation of oxygen found in the stream (site A) may be related to two processes: a) the respiration of microorganism, which promotes the decomposition of the high organic matter content (high DBO_5) coming from the leachate; b) the high oxidation (nitrification) processes of the ammoniacal nitrogen as the decomposition product of the organic matter. These can explain the high nitrite and nitrate concentrations at the site A (Fig. 3).

The excess of nitrogenated compounds in the aquatic environment is not directly toxic to the organisms, except the ammonia. However, when associated to the contributions of phosphate they may cause water eutrophication. This process of unbalanced nutrients provokes blooms of primary producers, mainly cyanobacteria. Cyanobacteria are opportunist organisms, that proliferate in detriment of the natural species and, thus, reducing the diversity of the aquatic environment. Besides this they can cause serious damages to the visual aspect of the environment and to the water uses (Esteves, 1998). The water eutrophication was demonstrated by the high chlorophyll (a) concentrations found in the stream, provably favored by the high organic matter content, and consequently high concentrations of nutrients, and also little circulation and depth in the waterstream.

Although a high level of contamination of nitrogenated compounds was observed in the stream, the same contamination was not found at the site D (in the Saco do Martins). This indicates that these compounds have a decrease probably due two processes: a) assimilation of these compounds by the salt marsh vegetation, and b) dilution and dispersion of the leachate in the salt marsh. This environment could be acting as a natural filter for the pollutants originated in the dump site. Another possibility for the decrease on the pollutant concentrations in the Saco do Martins could be their infiltration in the underground water of the dump site, causing contamination on the phreatic zone.

The income of organic matter in high intensity to this stream was confirmed by the high values of suspended organic material and BOD_5 analysis at the sites next to the dump site's nucleus. This contamination decreased significantly in the direction of the site D, probably due to the decomposition that this organic material suffered along its passage through the stream until arriving in the Saco do Martins.

The occurrence of a maximum peak of BOD_5 in the site B was a consequence of the almost null flow of the water in that place (increasing the residence time), accumulating the organic debris from the dump site.

Therefore, the intense contamination of the waters of the stream in the area next to the dump site proves that the leachate and the polluted stream are important sources of chemical compounds which pollute the waters of the Saco do Martins in the area immediately adjacent to the dump site.

At the site D, the aeration of the water is favored by the movement of the water circulation in the Saco do Martins. This increased the resuspension of the sediments, the concentration of debris deposited and carried to that place and explained the punctual increase of depth, as well as of the dissolved oxygen and its saturation, of the suspended material and its mineral fraction.

The pH values have a slightly increase along the stream until it reached the Saco do Martins. A little more acid environment was observed near the dump site, as a result of respiratory processes (which liberate carbonic gas) of organisms during the decomposition of the abundant organic matter in that area. However, this acidification was relieved by the simultaneous occurrence of the ammoniacal nitrogen oxidation (nitrification, which liberates hydroxyls for the environment) (Esteves, 1998; Mack & Bolton, 1999), identified by high concentrations of nitrite and nitrate in the area. The pH increase along the streamwater in direction to the estuary (site A to site D) was due the mixohaline water condition of the Saco do Martins. Comparing to the legislation (CONAMA, 2005), the pH values registered in the stream were inside the recommended limit (between 5 and 9).

The increase of metal concentrations from site A to site D can be explained by the sediment resuspension, since suspended material also presented an increase (Fig. 3). This indicates that the metal remobilization from the sediment to the water column can easily occur, mainly because of the wind regimen, since the stream is relatively shallow.

The high Pb concentrations in the water can be originated from the sediment remobilization, since Pb has preference to adsorb to silt and clay particles of the suspended material, as well as to the particles of the sediment (WHO, 1989). The problem of the leachate contamination stands out, since the concentrations of Pb exceeded on average 2.4 times the maximum value stipulated by the CONAMA (2005) for effluent launching (Tab. I). However, the concentrations of Cd were below the values recommended by the legislation.

Estuary

Space variation

The space variation of the parameters analyzed in the estuary indicated that the lowest values of oxygen and its saturation and the highest concentrations of ammoniacal nitrogen, nitrite, nitrate and chlorophyll (a) were along the sites near the margin (Fig. 1, 4 and 6, sites 1 to 5), independent of the water regimen or salinity probably as consequence of the contribution of the highly polluted rejects from the dump site. In addition, the shallow waters and the poor water circulation in that marginal area of the Saco do Martins made the water aeration more difficult, reducing its oxygenation and the dispersion of the runoff pollutant.

Being the nitrogenated compounds important nutrients for the primary producers, the high concentrations of these compounds, associated with the high values of chlorophyll (a), indicated development of eutrophication along the shore, although not as intensely as in the stream, since this one arrives diluted in the Saco do Martins.

Therefore, water contamination near the margin is very influenced by the dilution level of leachate contributions originated from of the dump site. The dilutions levels may vary according to the higher or lower hydrodynamic in the Saco do Martins.

The little variation of nitrite concentrations along the sites sampled in the channel, added to the increase of the nitrate concentrations (due to the good saturation of oxygen in those waters) indicated that the environment can autodepurate all excess of nutrients coming from the dump site. The occurrence of complete nitrification represented a good sign of environmental balance reestablishment of those channel waters.

The acidity peak measured in the waters near the margin might have been a consequence of a great microbiological degradation of the organic matter originated not only in the dump site, but also in the adjacent salt marshes occurring at those places.

In terms of suspended material and its mineral fraction, their highest concentrations were found in the places of smaller depth, evidencing that the dump site contributes with particles and debris to the immediately adjacent waters. This can be helped by the wind and drainage of the leachate, resuspending the fine sediments and residual material in the bottom of the water column.

The absence of significant difference among the margin and channel sites in relation to salinity, temperature, phosphate and ammonia was probably due the little relative distance among the sampling sites. The hydrodynamics of the estuary could have also homogenized the water of the study area.

Seasonal variation

The predominance of fresh water in the estuary during the spring was consequence of the rain period and of an intense ebbing regimen of the estuary.

Although the maximum concentrations of nitrogenated and phosphate compounds were registered at the sites sampled near the margin, in the presence of freshwater, the values of suspended organic material were not high. This can be explained by the decomposition of the organic matter along the stream, which predominantly drains to the Saco do Martins degradation products of the organic matter, including the nitrogenated and phosphate compounds.

Coinciding with the enrichment of nutrients, high concentrations of chlorophyll (a) were registered. Therefore, it was in the dominance of freshwater and ebbing regimen of the estuary that the dump site contributed with the highest water eutrophication in the margin of the Saco do Martins.

The lowest oxygen levels that occurred at the sites along the shore in low saline condition (spring, Fig. 4) might have been a consequence of the ammoniacal nitrogen oxidation process, resulting in the accumulation of nitrite in that area (Fig. 6). The low hydrodynamics in these areas during the sampling period probably had contributed as well for the low oxygenation of these waters.

The predominance of salt water in the estuary during the summer sampling was a consequence of the occurrence of the flooding regimen in the estuary, highly favored by a strong drought period, when the water level of the estuary decreased. This phenomenon was also observed for other years (Möller et al., 1991).

The entrance of seawater in the estuary at that time resulted in a decontamination of the water of the study area, including the ones near the margins of the dump site. This event reduced the impact caused by the emissions originating from the dump site. However, in this saline condition there were increments in the concentrations of phosphate in all sampled sites, including the control site. This can probably be explained by the penetration of the seawater in the system, liberating the interstitial water usually richer in many elements, and also phosphate, to the water column. In addition, the increase of the ionic force caused in the sedimentary column, could desorbs or redissolve phosphate particles deposited near the sediments, increasing the concentrations of phosphate in the water column, as it was described by Baumgarten et al. (2005).

The predominance of mixohaline water during the autumn and winter sampling occurred due to the mixtures of fresh- and seawater. This creates the predominant saline condition in the area, previously described for the Saco do Justino, adjacent to Saco do Martins (Baumgarten et al., 2005).

On this occasion, the pH values in the water were higher than the ones registered in the presence of seawater. This was not expected, since that last one usually presents slightly alkaline pH. The probable cause of this pH increase is the oxidation of the ammoniacal nitrogen forming nitrite. This reaction liberates hydroxyls in the environment and it can contribute to increase the pH in the water (Esteves, 1998 ; Mack & Bolton, 1999).

The increase of the ammonia in the water in this saline condition is related to the pH variation. The relative concentrations of ammonia (NH_3, non ionized form) and ammonium (NH^+_4, ionized form) vary with the pH, as well as with the temperature and ionic forces of the aquatic environment. As the pH increases, the balance tends to the non ionized ammonia form, increasing the concentrations of ammonia and reducing the concentrations of ammonium. An increase of one unit of pH causes an increase of an order of magnitude in the concentration of ammonia (Rand & Petrocelli, 1985; Binkley et al., 1999). In relation to the toxicity, the non ionized form (ammonia) is the fraction of ammoniacal nitrogen that possesses toxic effects, while the ammonium is not considered toxic or significantly less toxic (Emerson et al., 1975). However, the toxicity of the ammonia decreases with the increase of the pH (Binkley et al., 1999).

The peaks in the phosphate concentrations registered in some sites away from the margin might have been a consequence of the contributions from the interstitial water, as already focused for the dominance of the salted waters. The presence of phosphate in these waters might have also been favored by the low simultaneous concentrations of suspended material, once the phosphate can easily be adsorbed in those particles, when very concentrated in the water, and thus be no more considered as dissolved phosphate (Eyre, 1994; Li et al., 2006).

Impact of the Dump Site

The impact caused by the municipal dump site of Rio Grande City in the salt marsh area and in the shore of the Saco do Martins was evident, although the pollutant dispersion in the Saco do Martins is favored by the different and very varied water regimen that occur in this environment.

Chemical characteristics of the leachate in the stream at site A, closed point to the dump site, indicated low values for most parameters when compared to dump sites of other countries (Tab. II). Exception was found for the lead concentration, which presented similar concentration of this element at the Mpererwe dump site of Uganda, although in this last site rude sample was analyzed without any dilution, while the one from Rio Grande was diluted during its passage through the salt marsh. However, Pb concentration indicated to be

Table II: Chemical caracteristics (mean values) of leachate samples from different locations compared to the site A of the Rio Grande dump site and the maximum limits of the legislation for effluent launching.

Location	pH	Ammoniacal nitrogen (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)	BOD_5 (mg/L)	Pb (mg/L)	Cd (mg/L)	Author
Rio Grande's dump site	7.50	21.41	35.05	0.06	0.035	45.89	0.93	0.023	Present study
Ano Liosia landfill (Greece)	8.34	1131	-	-	15.5	718	0.50	0.03	Fatta et al. (1999)
El Jadida landfill (Marroco)	8.8	105	2	-	-	60	-	34	Cholqi et al. (2004)
El Yahoudia dump site (Tunisia)	7.43	-			-	8160	0.44	ND	Zaïri et al. (2004)
Mpererwe' dump site (Uganda)	8.27	1403.67	61.50	3.97	34.63	1545.67	0.93	-	Mwiganga & Kansiime (2005)
Legislation limit	5 to 9	20	-	-	-	-	0.50	0.20	CONAMA (2005)

ND = not detected

higher than the limits recommended by the Brazilian legislation.

The probable source of Pb in the dump site can be electric batteries and metallic structures, which were deposited in this area. Considering that the properties next to the dump site possess artesian wells, used for water consumption up to recently, it becomes important to determine the degree of contamination of the underground water of that area.

The excess of nitrogenated compounds from the leachate indicated also contamination in the study area, which associated to the availability of phosphate in the Saco do Martins may promote the occurrence of blooms of primary producers, mainly cyanobacteria.

Therefore, the sanitary landfill should become a reality as soon as possible. Measures to recover the dump site area are extremely important, for both the environment and the society. Such measures would only mitigate the impact that has been provoked for more than 30 years, since the environmental liability will stay in the area.

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